Pathways to Deep Decarbonization

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DDPP DEEP DECARBONIZATION PATHWAYS PROJECT

NREL Workshop
June 9, 2016

Pathways to Deep Decarbonization

- DDPP Background
- Why Long-Term Pathways?
- Research Questions & Methods
- High Level Results
- Sectoral Transitions
- Electricity System
- Observations on Nuclear-Renewable Synergies

Background

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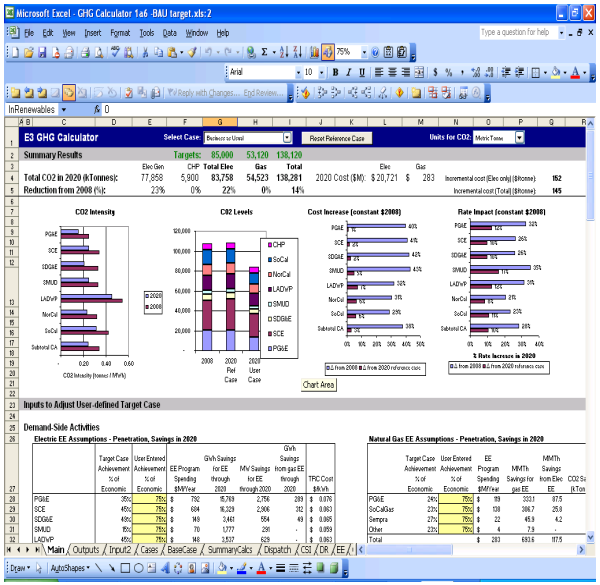
California Pathways Analysis



2008


Science
AAAS

The Technology Path to Deep Greenhouse Gas Emissions Cuts by 2050: The Pivotal Role of Electricity
James H. Williams, *et al.*
Science **335**, 53 (2012);
DOI: 10.1126/science.1208365

The Technology Path to Deep Greenhouse Gas Emissions Cuts by 2050: The Pivotal Role of Electricity

James H. Williams,[1,2] Andrew DeBenedictis,[1] Rebecca Ghanadan,[1,3] Amber Mahone,[1] Jack Moore,[1] William R. Morrow III,[4] Snuller Price,[1] Margaret S. Torn[3]*

Several states and countries have adopted targets for deep reductions in greenhouse gas emissions by 2050, but there has been little physically realistic modeling of the energy and economic transformations required. We analyzed the infrastructure and technology path required to meet California's goal of an 80% reduction below 1990 levels, using detailed modeling of infrastructure stocks, resource constraints, and electricity system operability. We found that technically feasible levels of energy efficiency and decarbonized energy supply alone are not sufficient; widespread electrification of transportation and other sectors is required. Decarbonized electricity would become the dominant form of energy supply, posing challenges and opportunities for economic growth and climate policy. This transformation demands technologies that are not yet commercialized, as well as coordination of investment, technology development, and infrastructure deployment.

2012

2014

2015: California Executive Order B-30-15: reduce greenhouse gas emissions to 40 percent below 1990 levels by 2030

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- Deep Decarbonization Pathways Project
  - National blueprints for limiting warming to 2°C
  - Independent research teams from 16 countries
  - 3/4 of current CO_2 emissions
  - Moving from incrementalism to transformation
  - Backcasting: how do we get there from here?

deepdecarbonization.org

SCIENCE

A Path for Climate Change, Beyond Paris

By JUSTIN GILLIS DEC. 1, 2015

UN issued with roadmap on how to avoid climate catastrophe

Report is the first of its kind to prescribe concrete actions that the biggest 15 economies must take to keep warming below 2C

Paris Agreement, Article 4, Paragraph 19 "All Parties should strive to formulate and communicate long-term low greenhouse gas emission development strategies…"

Why long-term pathways are essential

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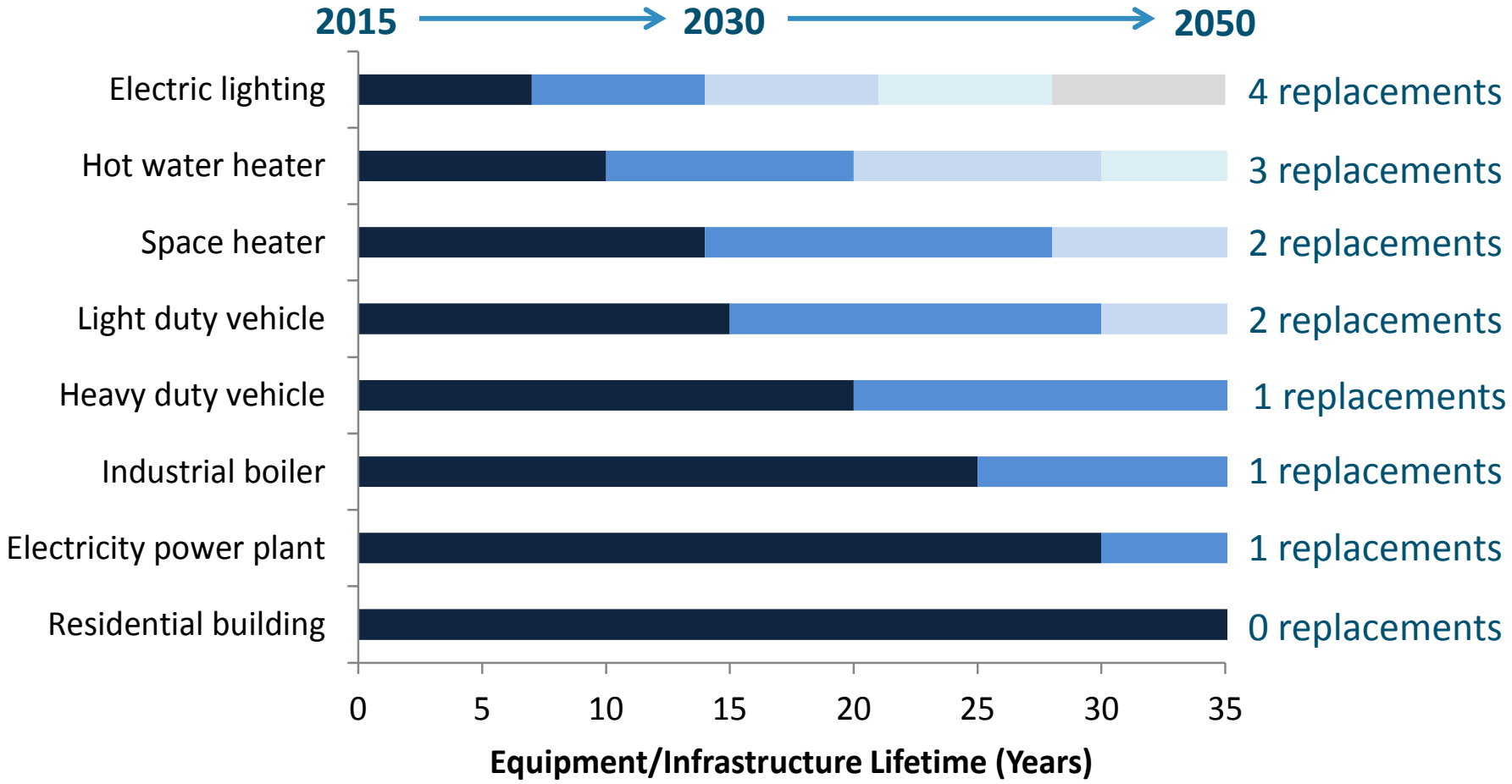
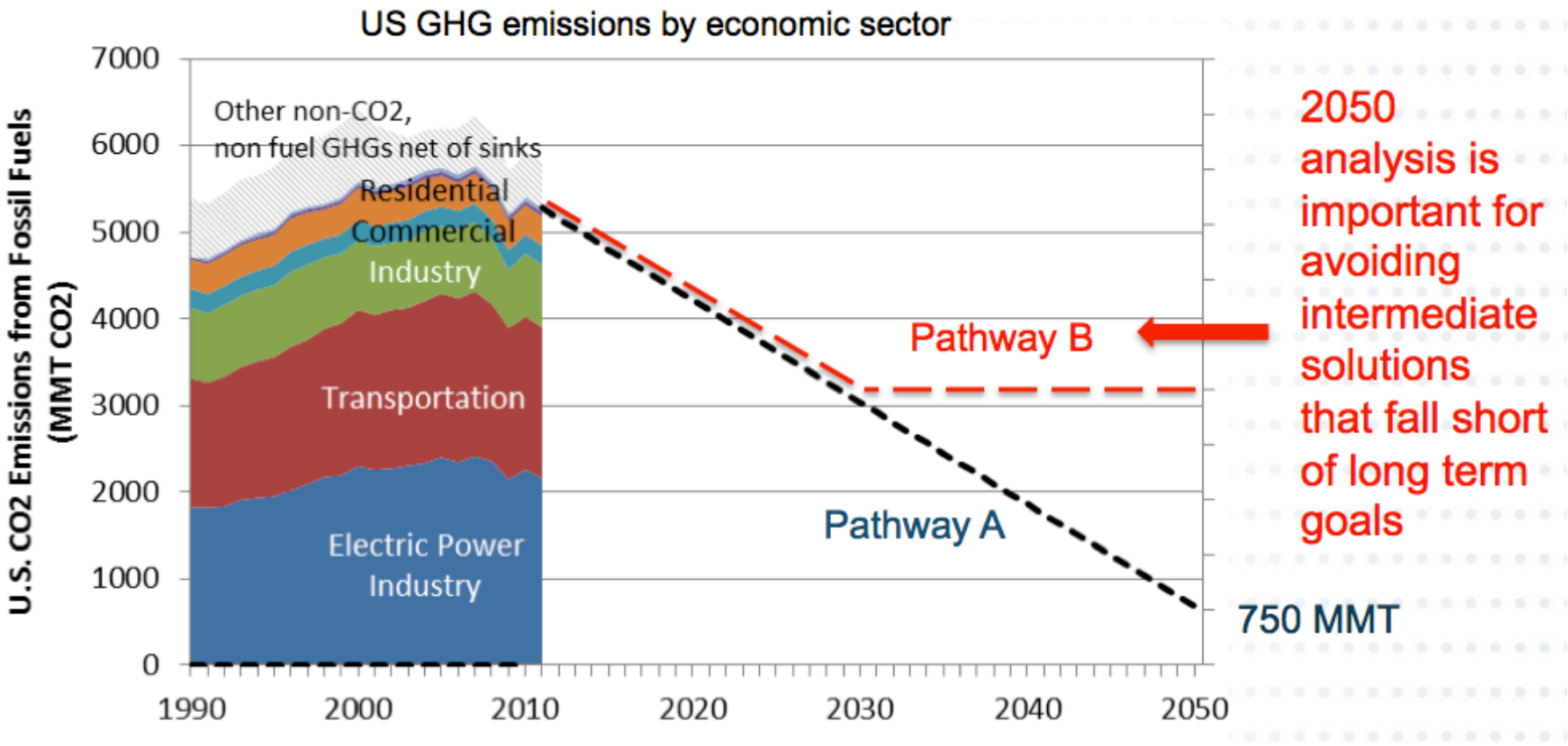
Long Equipment Lifetimes on Supply and Demand Side of Energy System

- A car purchased today is likely to replaced at most 2 times before 2050.
  A residential building constructed today is likely to still be standing in 2050.



Avoiding emissions dead ends



Anticipating forks-in-the-road: Real example from California

1. Electric vs. Fuel Cell Vehicles

Zero Emissions Vehicles

Electric vehicles

Fuel cell vehicles

Electric charging infrastructure

H2 fuel production: grid electrolysis

2. Electrification vs. Low Carbon Gas in Buildings

Building strategy

Biogas and low-carbon synthetic methane

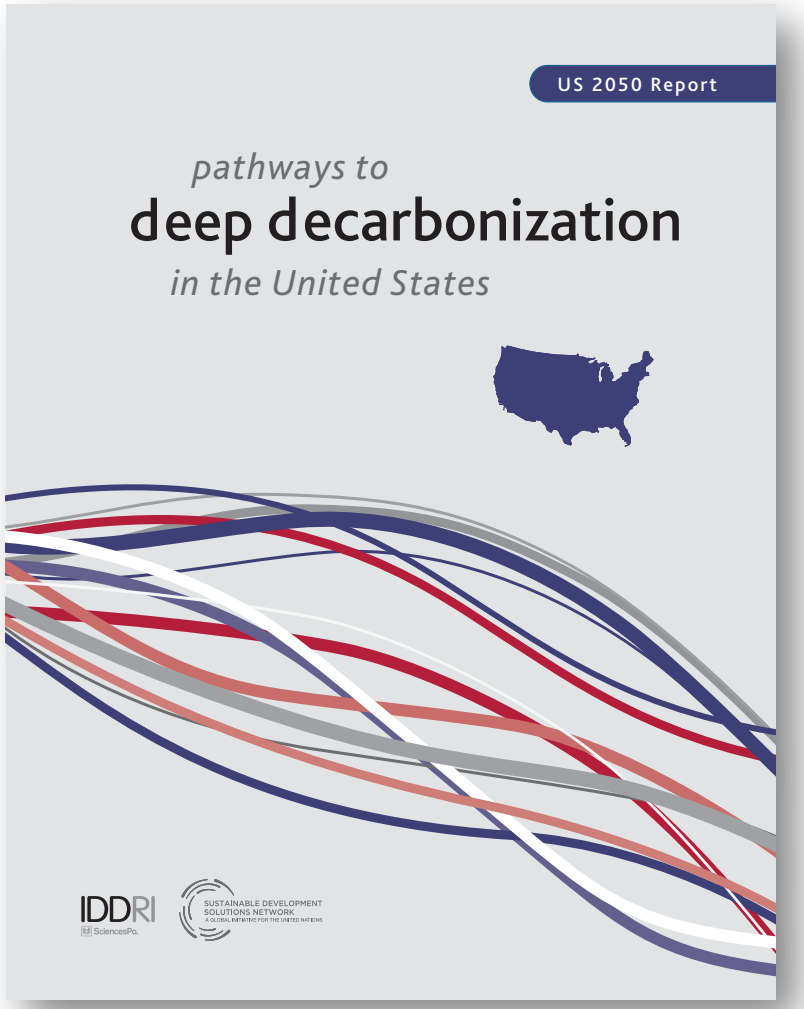
Electric heat pumps, electrification

No building electrification, biogas in pipeline

Building electrification, no gas pipeline

US Pathways Research Questions & Methods

U.S. Pathways Analysis



E3, UC, LBNL, PNNL team

Technical Report, Nov. 2014

What would it take for US to achieve 80% GHG reduction below 1990 level by 2050?

- ***Is it technically feasible?***
- ***What would it cost?***
- ***What physical changes are required?***

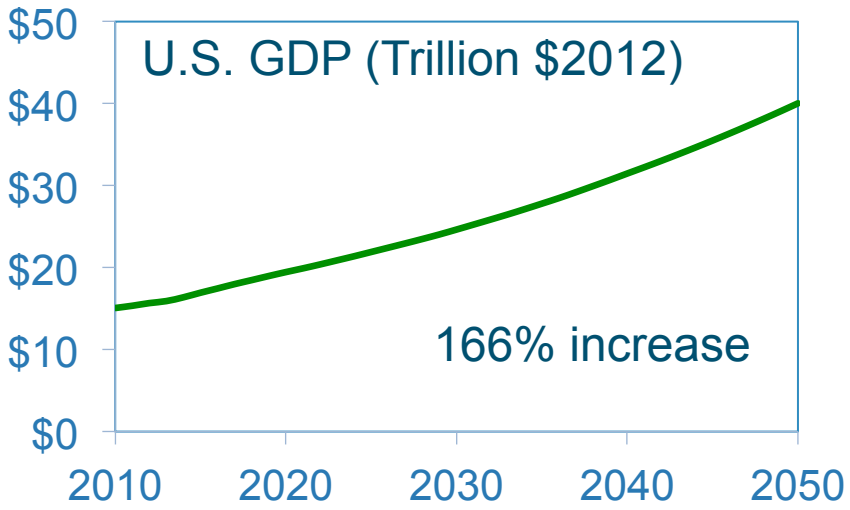
Policy Report, Nov. 2015

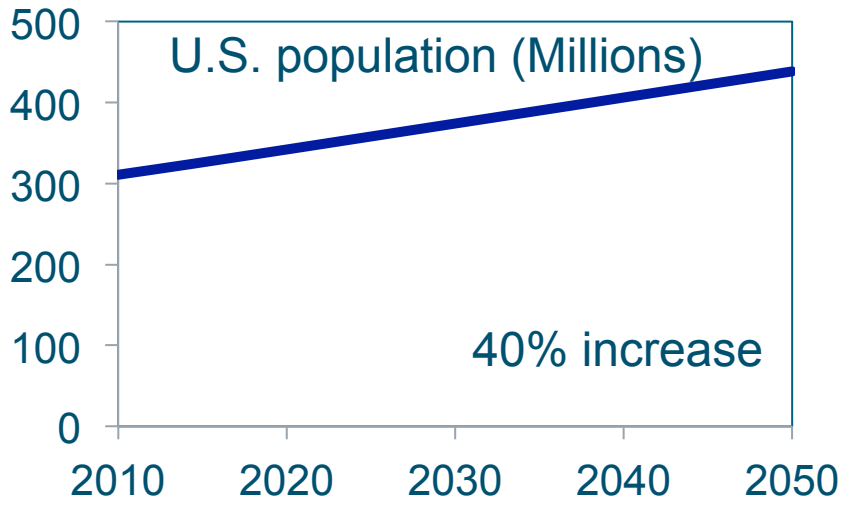
- ***What are the policy implications for the US?***

Reports available at http://usddpp.org

Scenario Design Constraints

- Infrastructure inertia
- Electric reliability
- Same energy services as EIA forecast
- Technology is commercial or near-commercial
- Environmental limits (biomass, hydro)

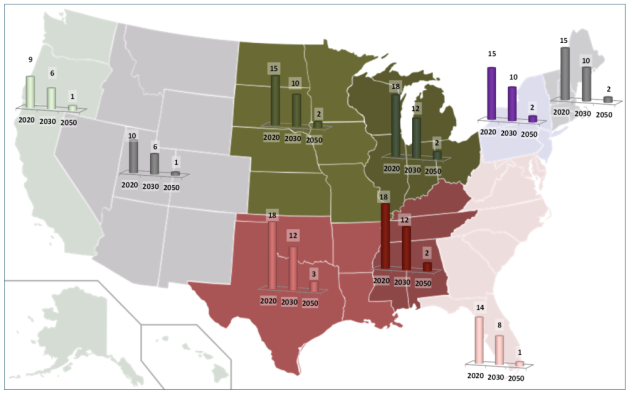




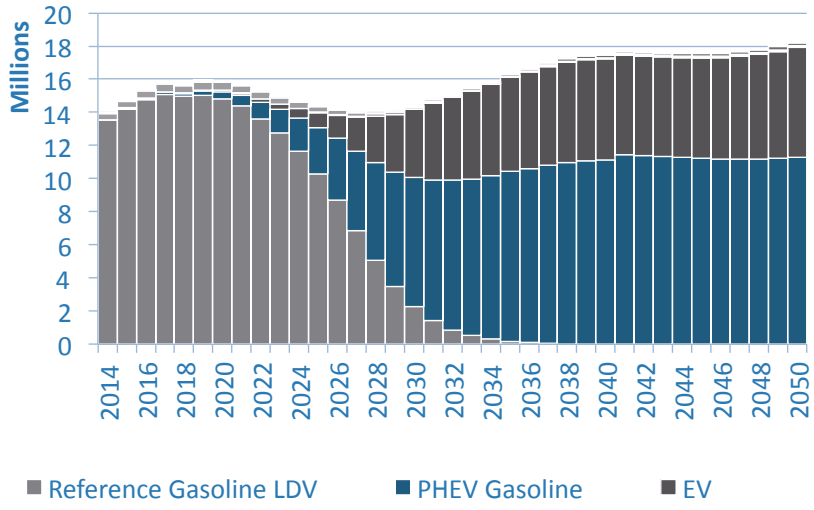
U.S. National Energy Modeling System and 2013 Annual Energy Outlook reference case

PATHWAYS Model

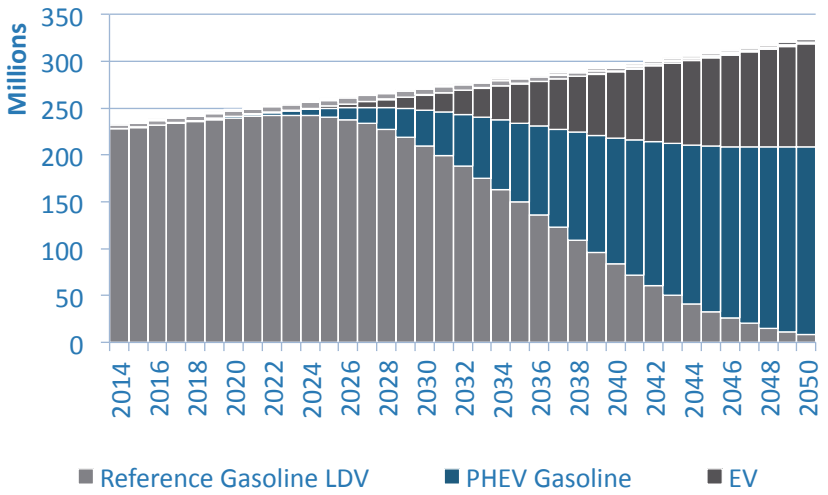
- Energy system model, user-defined scenarios
- 80 demand sectors, 20 supply sectors
- Annual time steps with equipment lifetimes
- 9 US census divisions separately modeled
- Electricity dispatch, three US interconnects



New Vehicles by Vintage

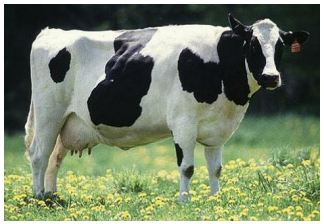


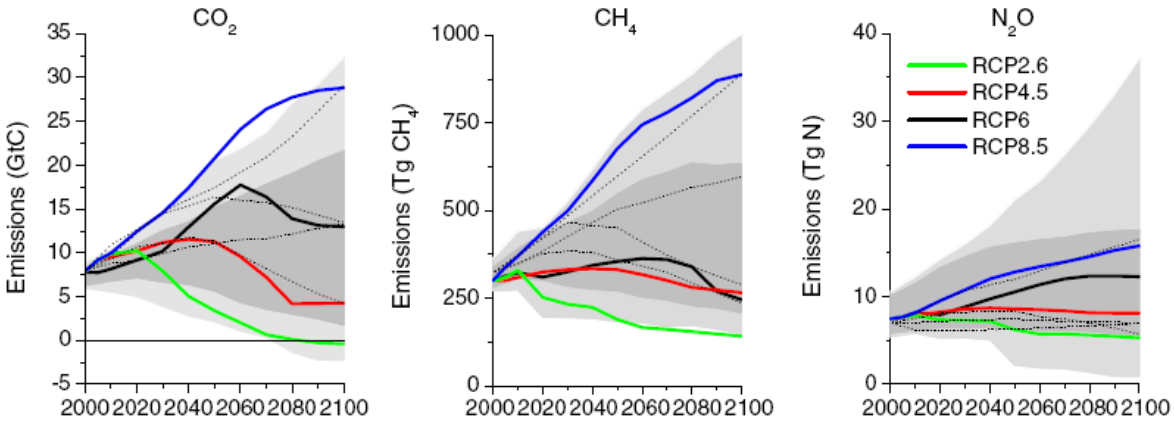
Total Stock by Year



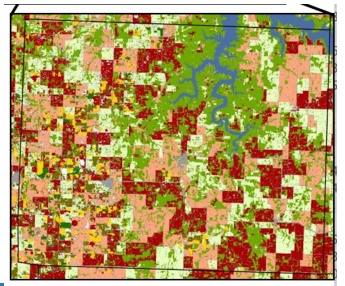
GCAM Used to Model Non-Energy and Non-CO_2 emissions

- Well-known IAM used in IPCC Fifth Assessment Report
- Biomass production and indirect land use change emissions
- Non-energy and non-CO_2 GHG mitigation
- Assess sensitivity to terrestrial carbon sink assumptions





IPCC 2014; van Vuuren et.al. 2011



US Pathways
High-Level Results

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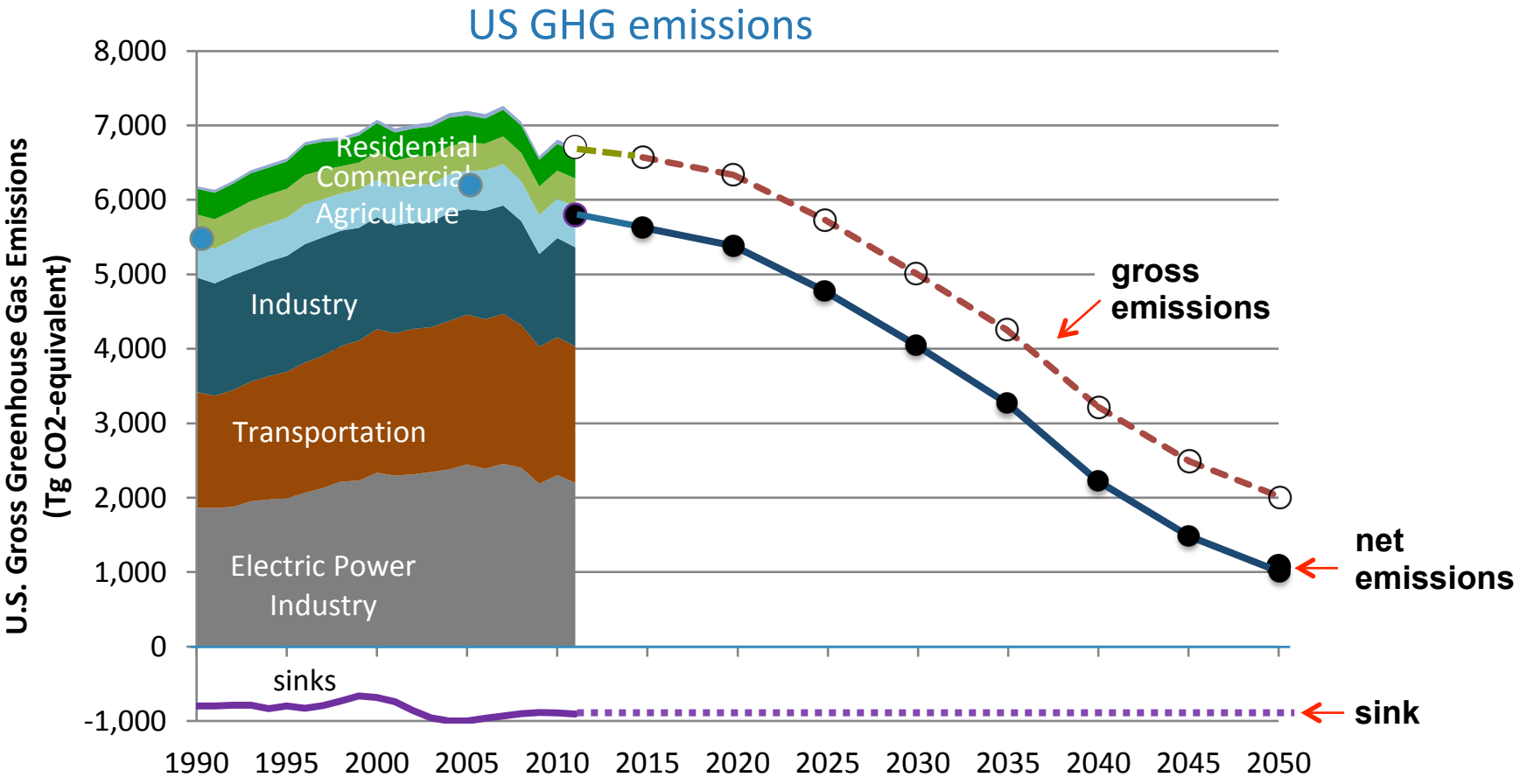
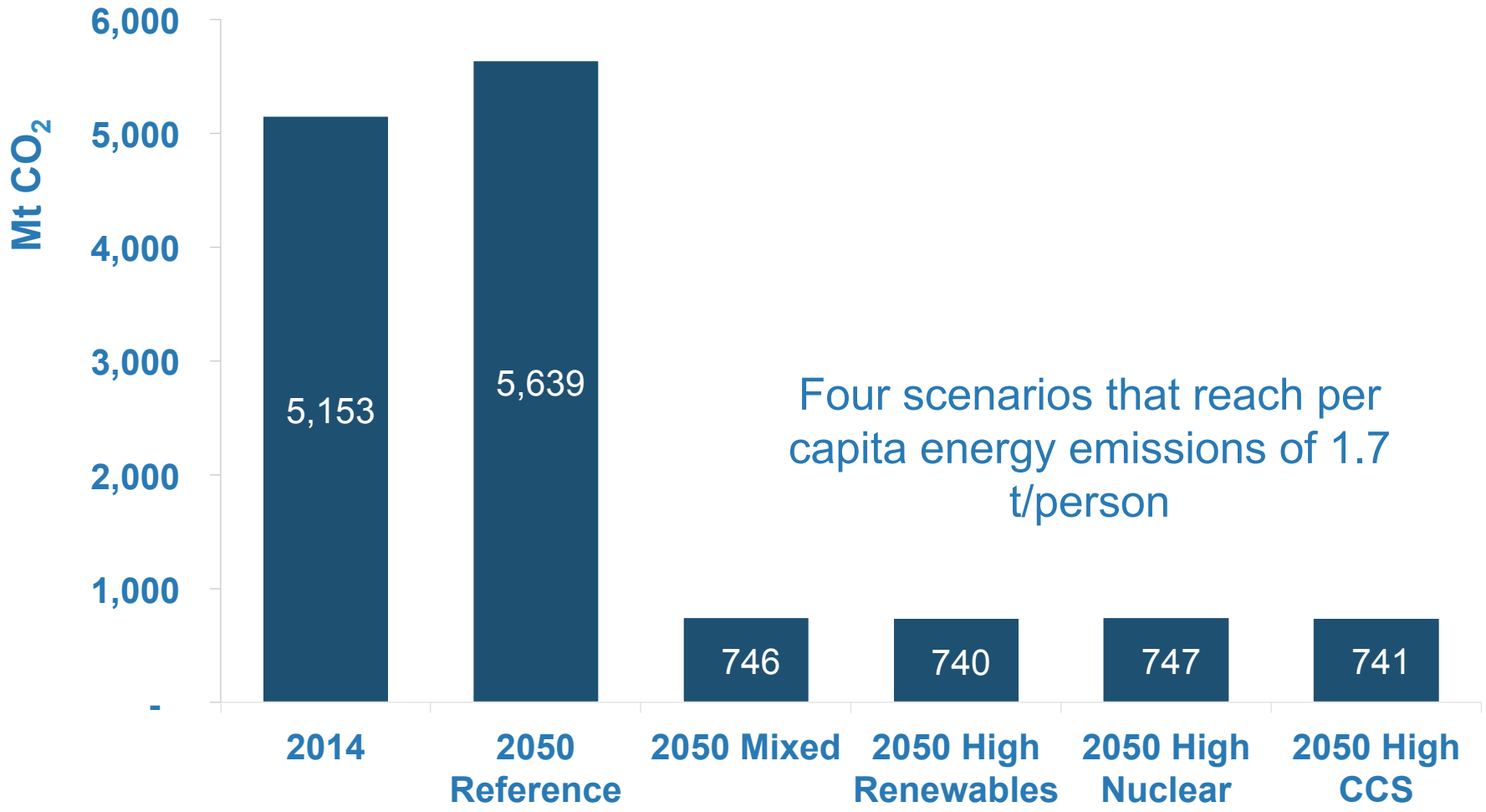
PROJECT

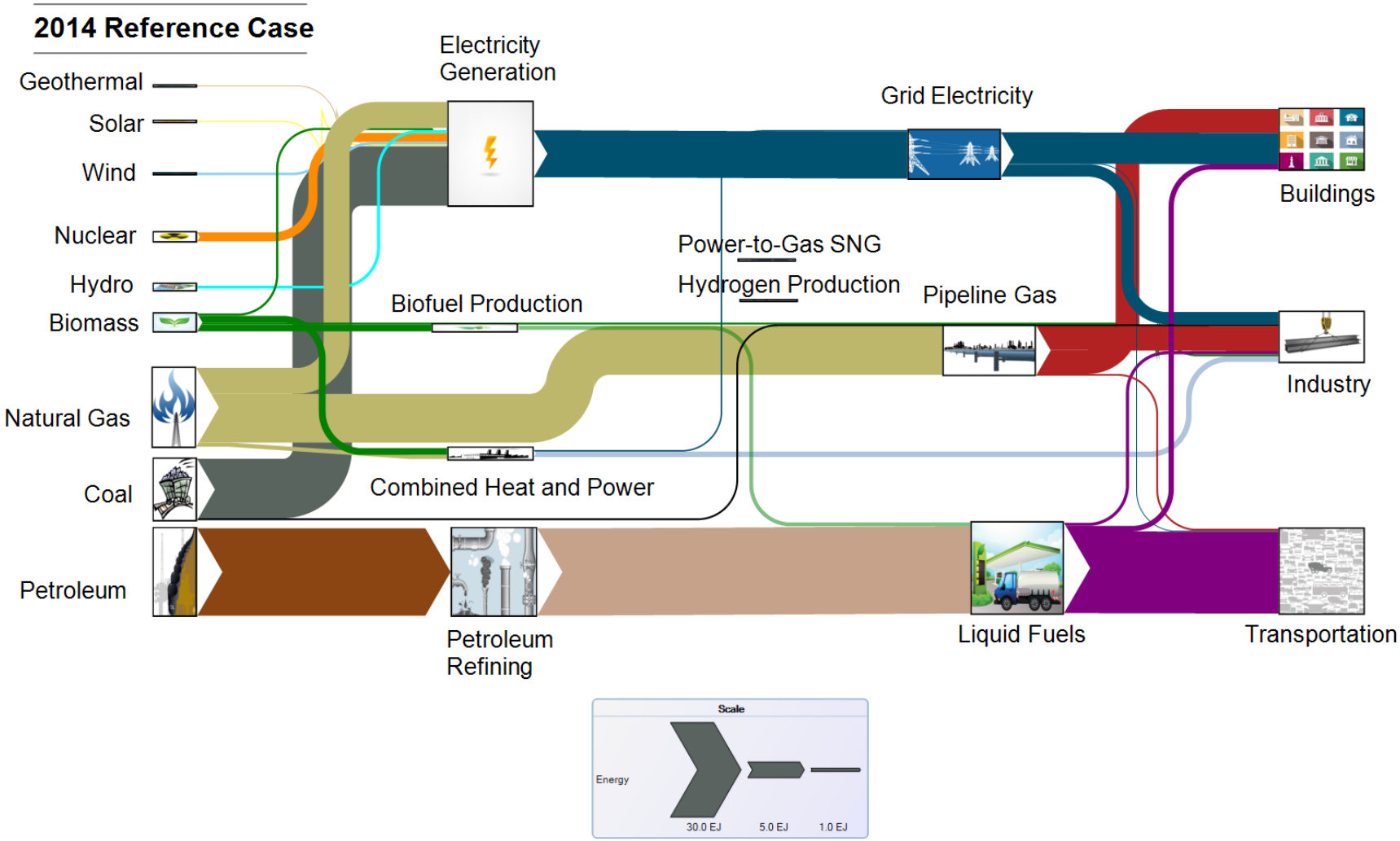
80% Reduction in CO_2e by 2050 is Achievable



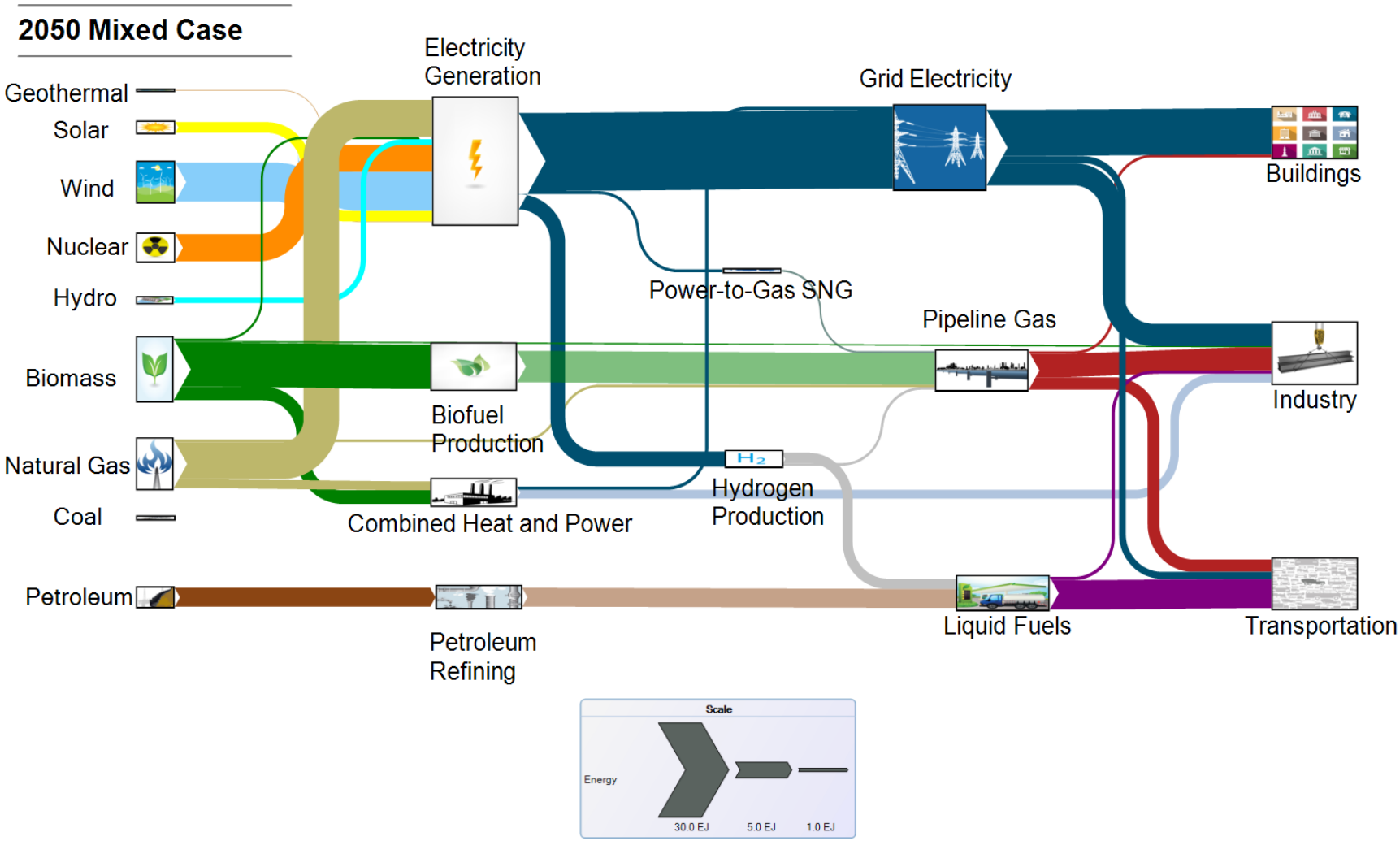
Multiple Feasible Technology Pathways Exist



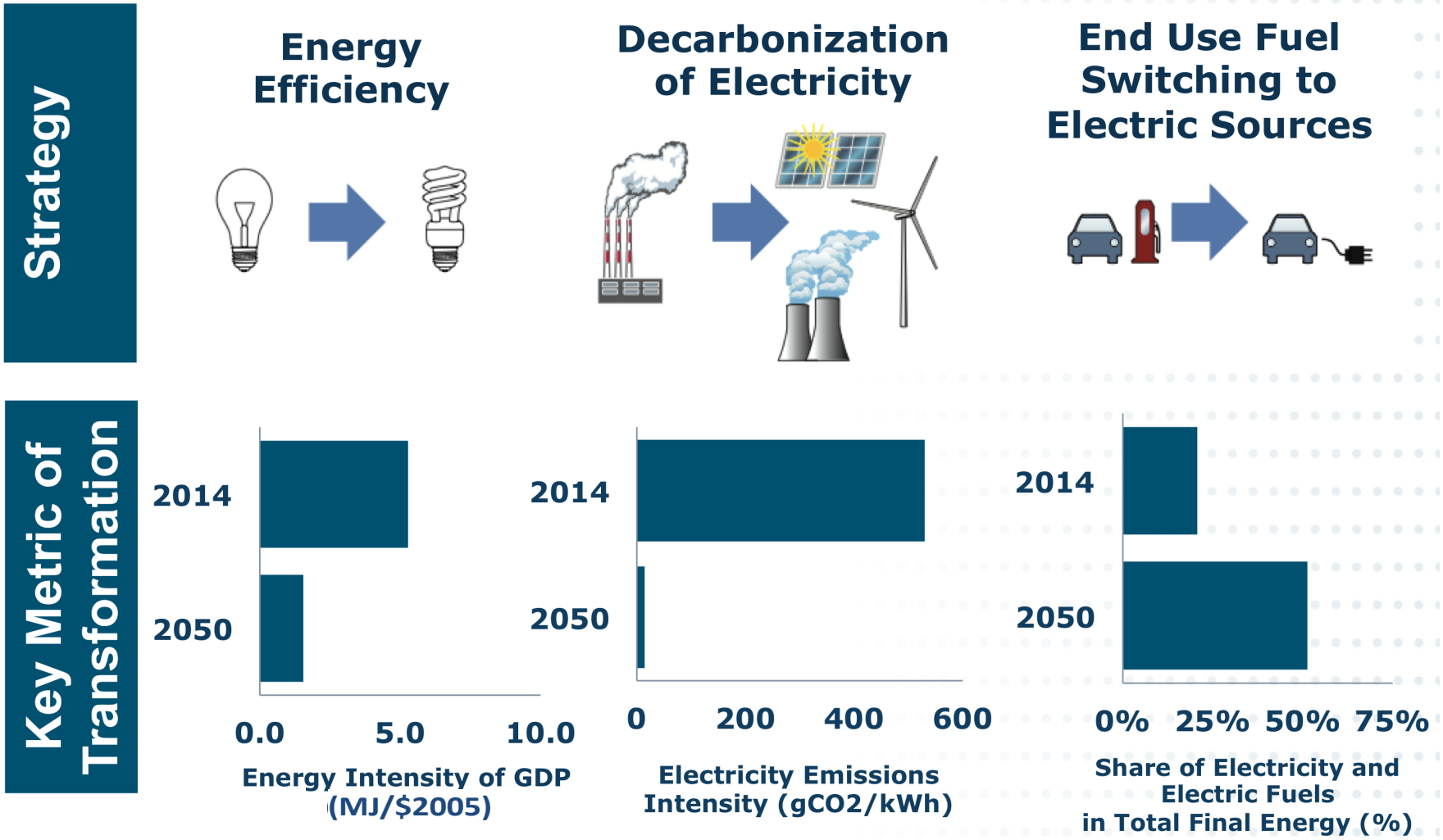
Current Energy System



Deeply Decarbonized Energy System



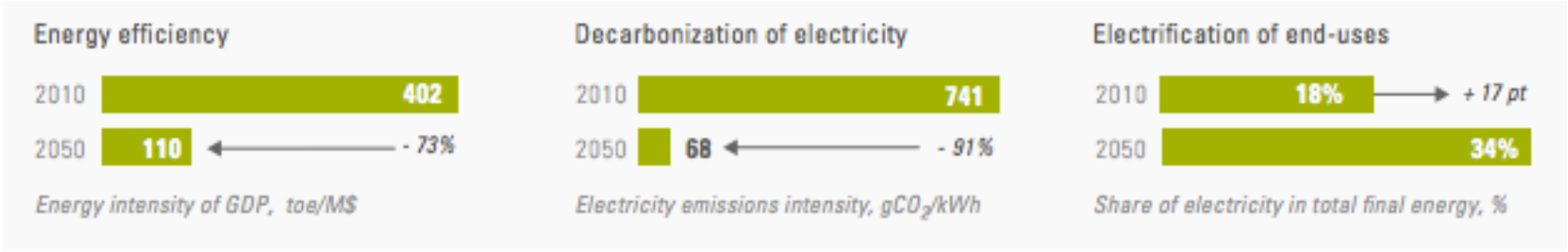
Three Pillars of Deep Decarbonization Required in All Cases



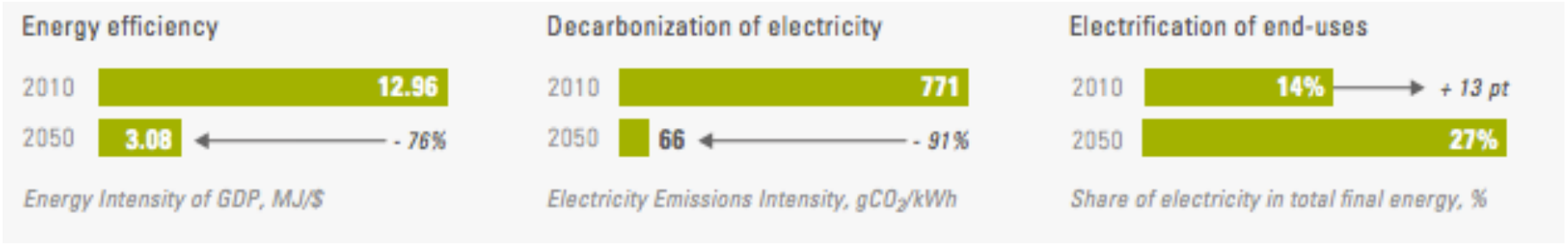
Pathways to Deep Decarbonization in the United States, Mixed case results

Three Pillars Results for China, India, UK

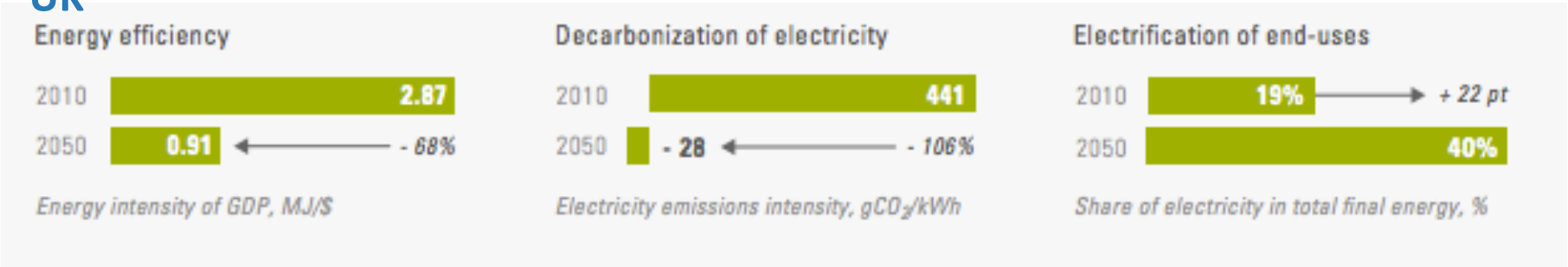
China



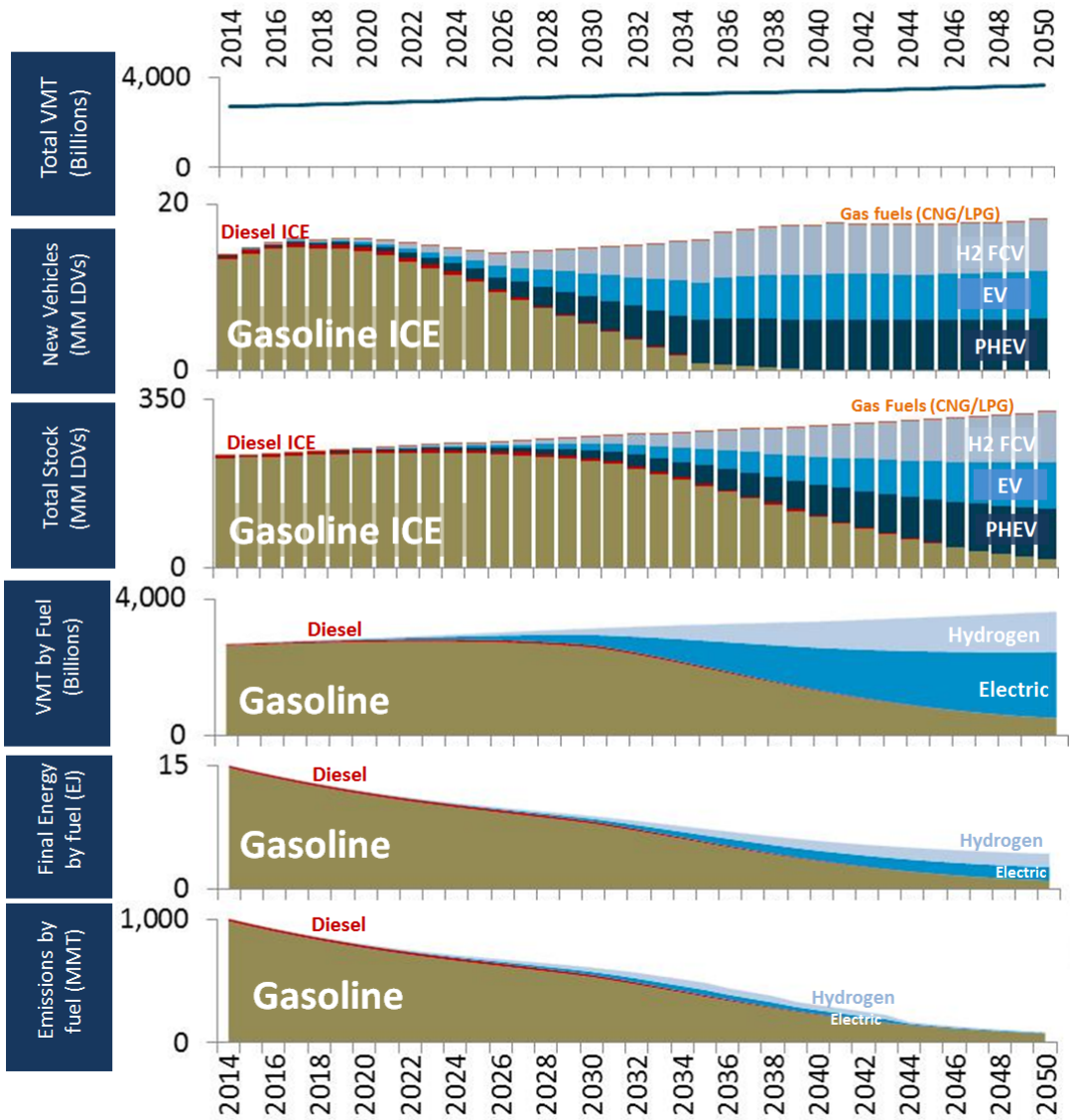
India



UK



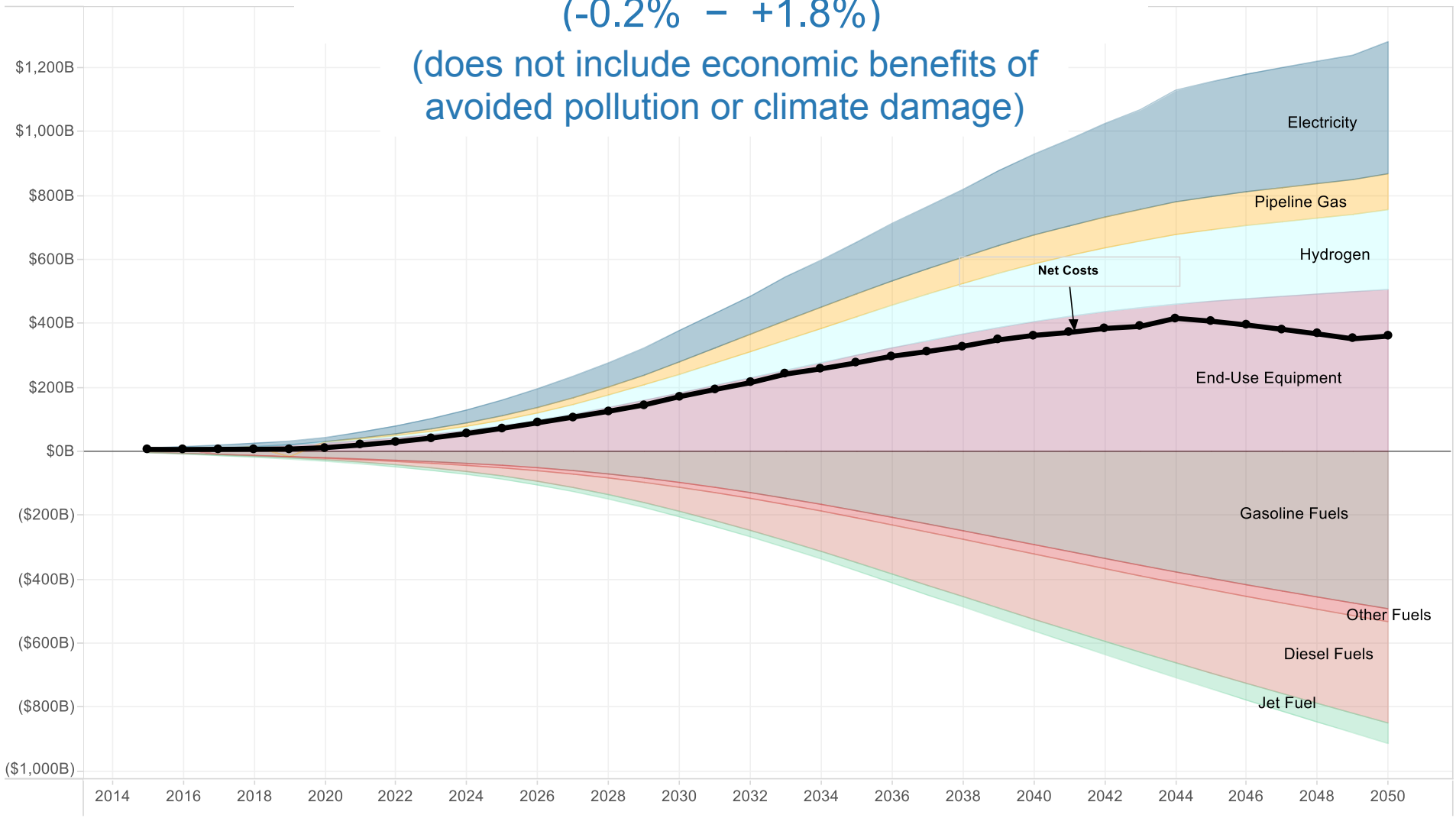
LDV Transition, Mixed Case



Deep Decarbonization is Affordable

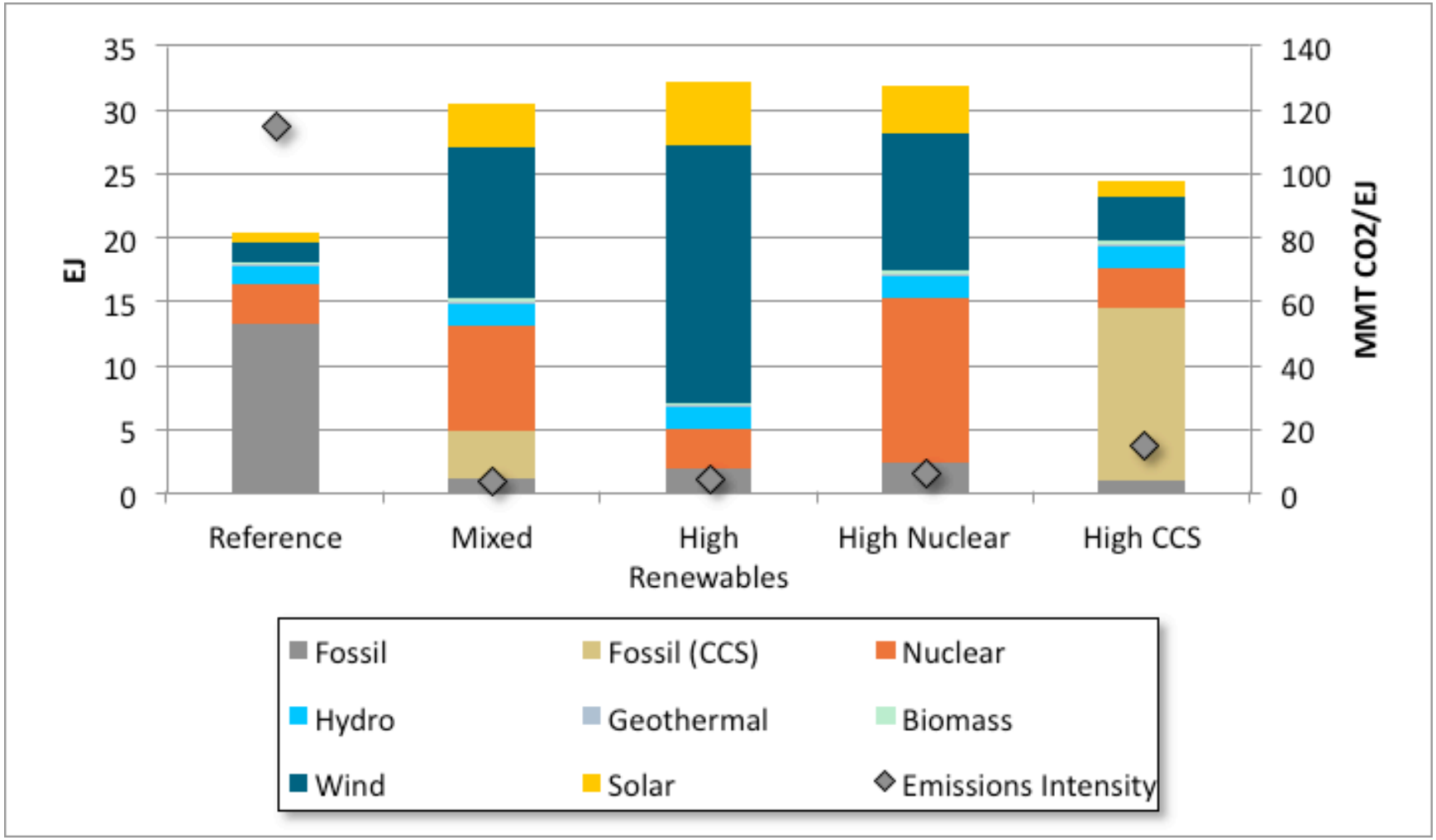
Net energy system cost in 2050 ~ 0.8% GDP
(-0.2% – +1.8%)

(does not include economic benefits of avoided pollution or climate damage)

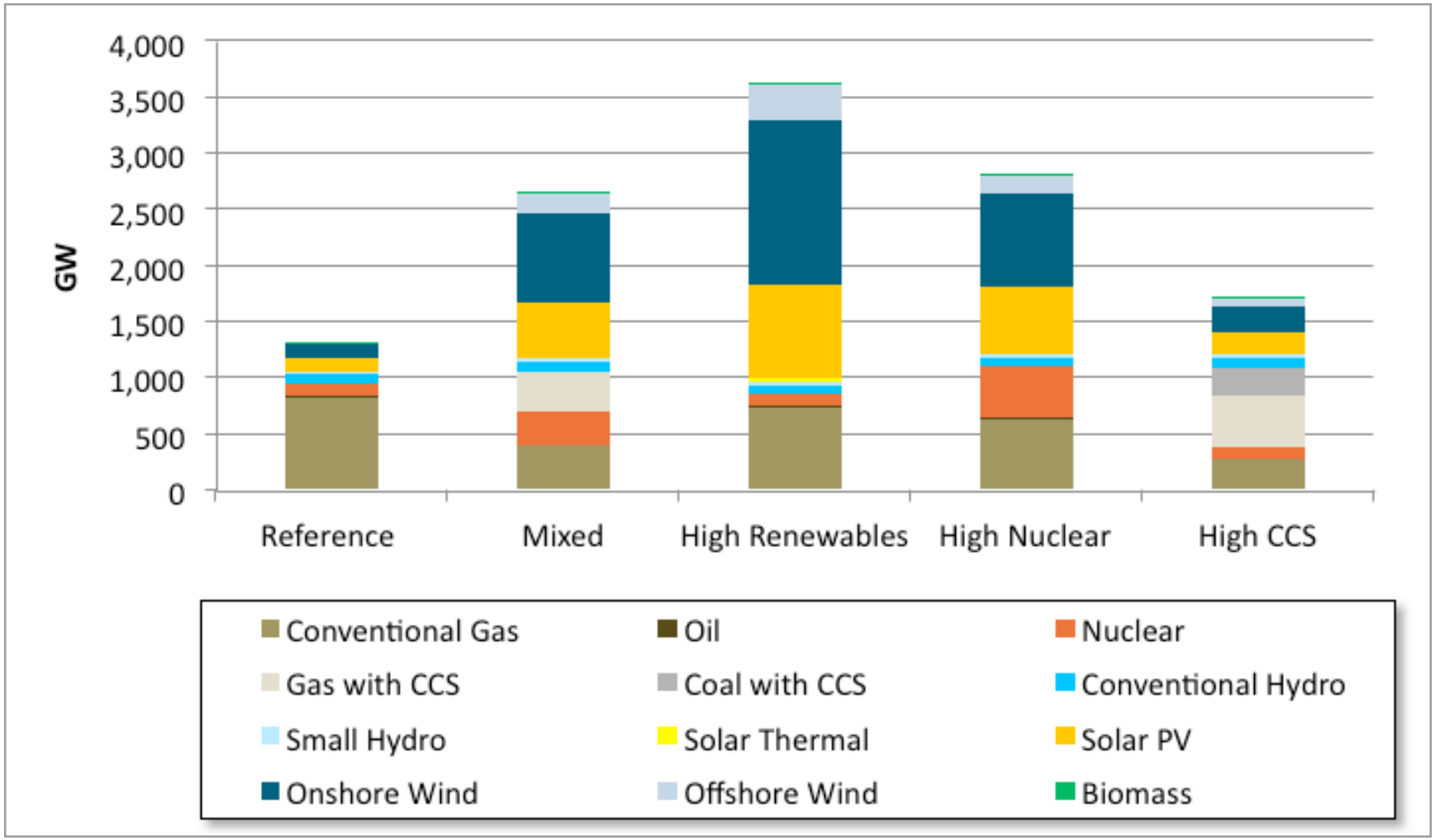


Electricity System

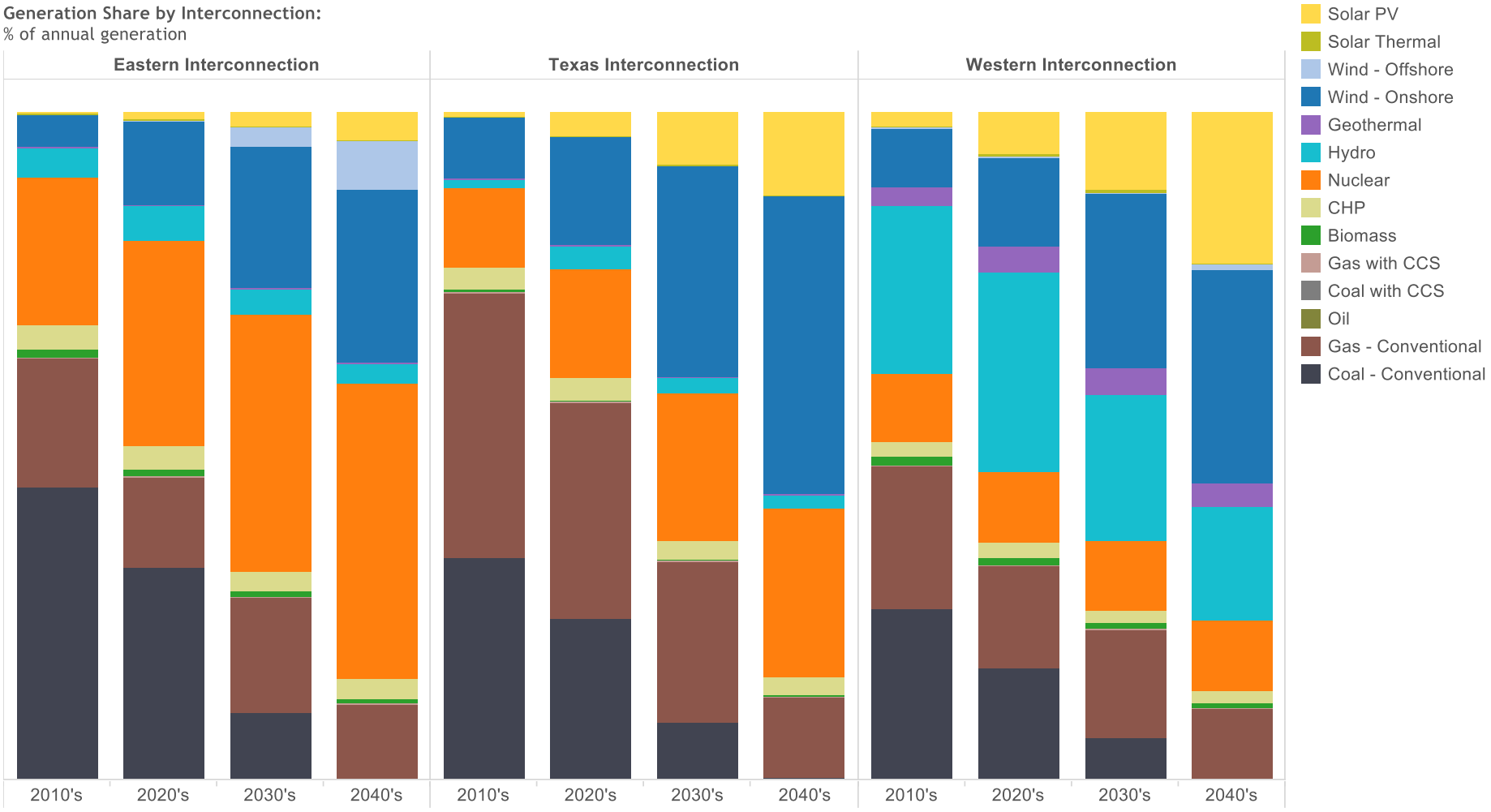
Electricity Generation by Type in 2050



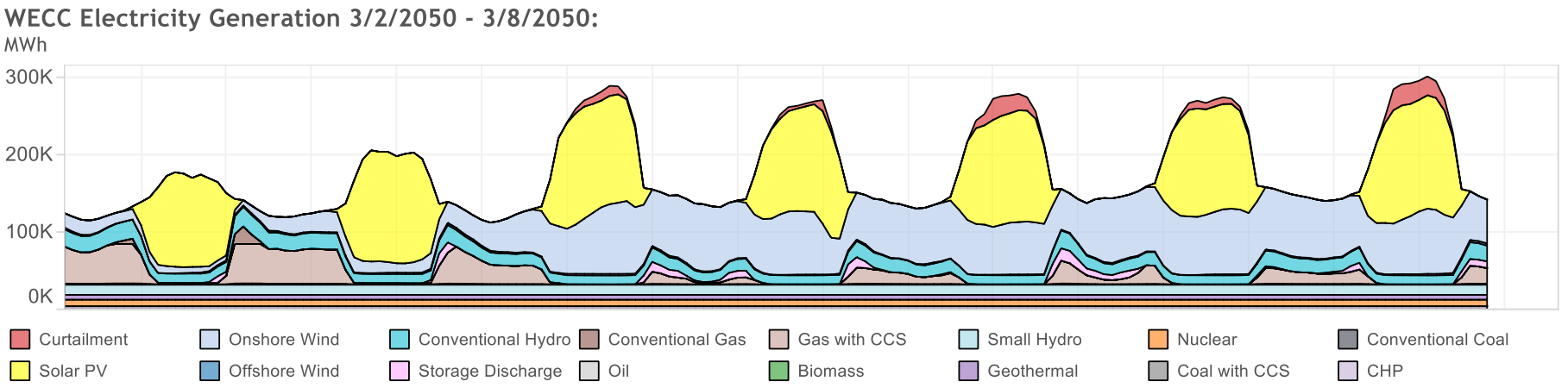
Generating Capacity by Type in 2050

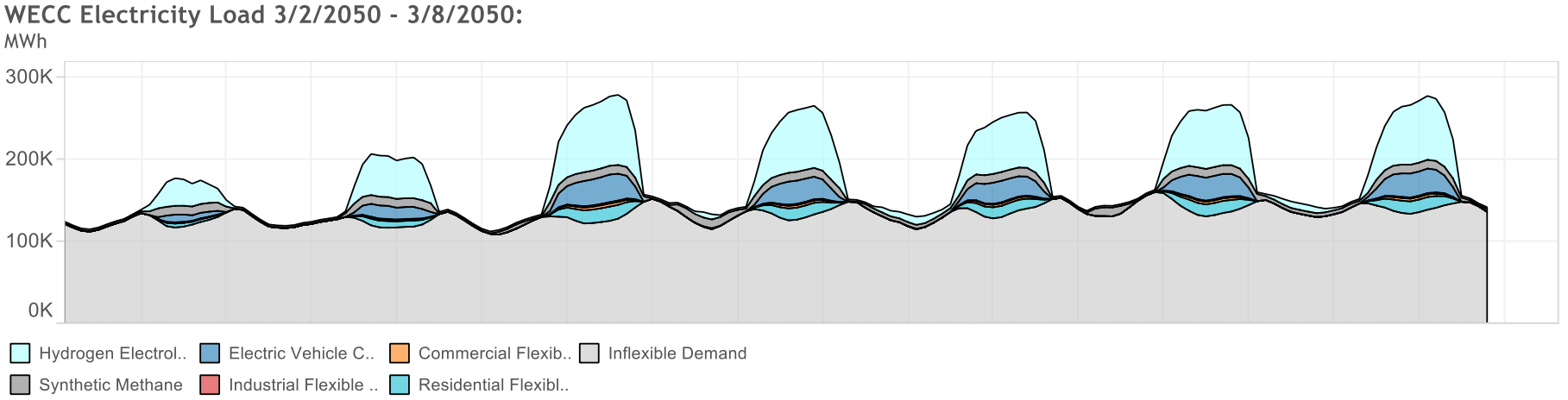


Generation Transition by Interconnect and Decade – High Nuclear Case

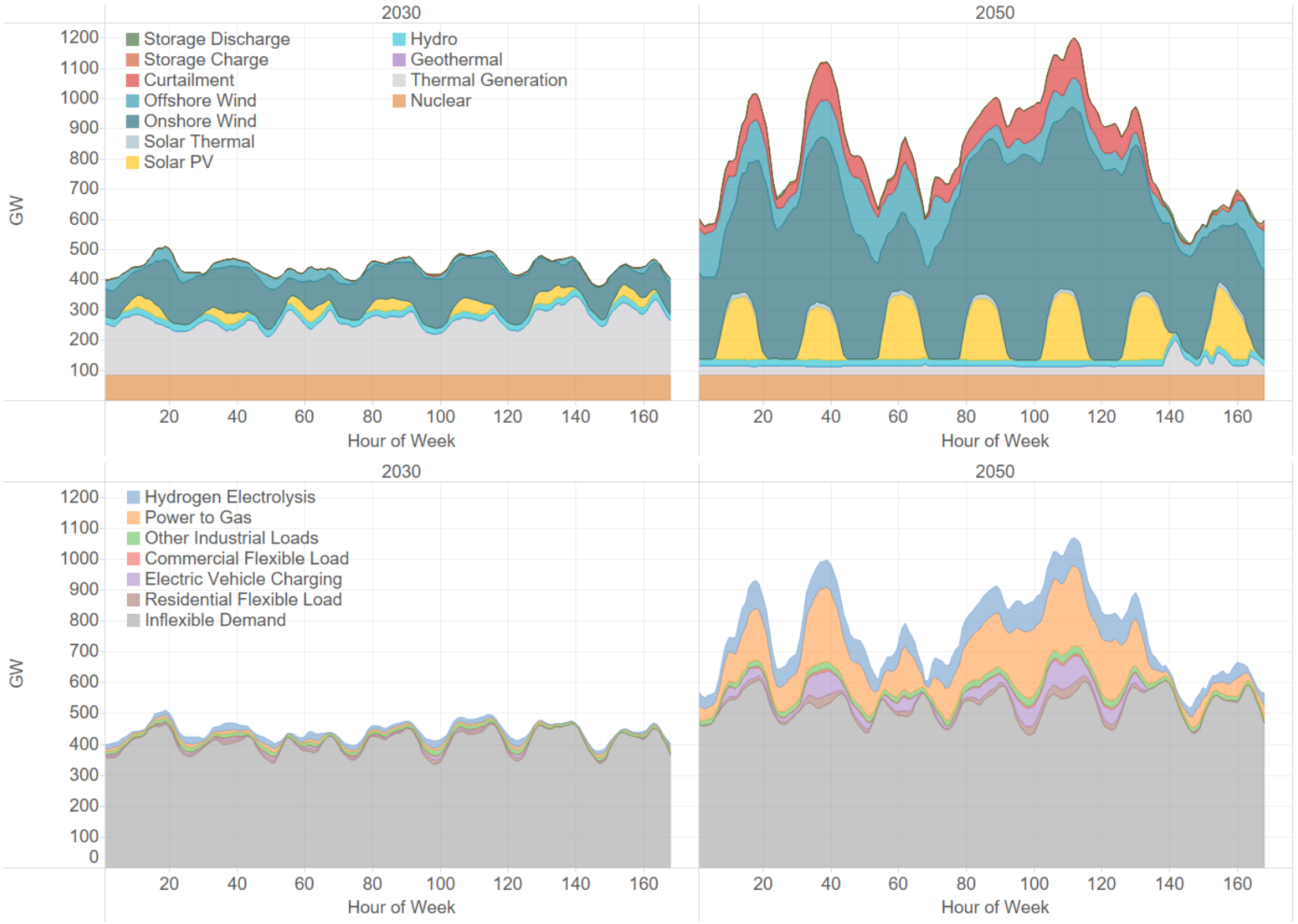


Hourly Electricity Supply & Demand in WECC, High Renewables Case, Week in March 2050

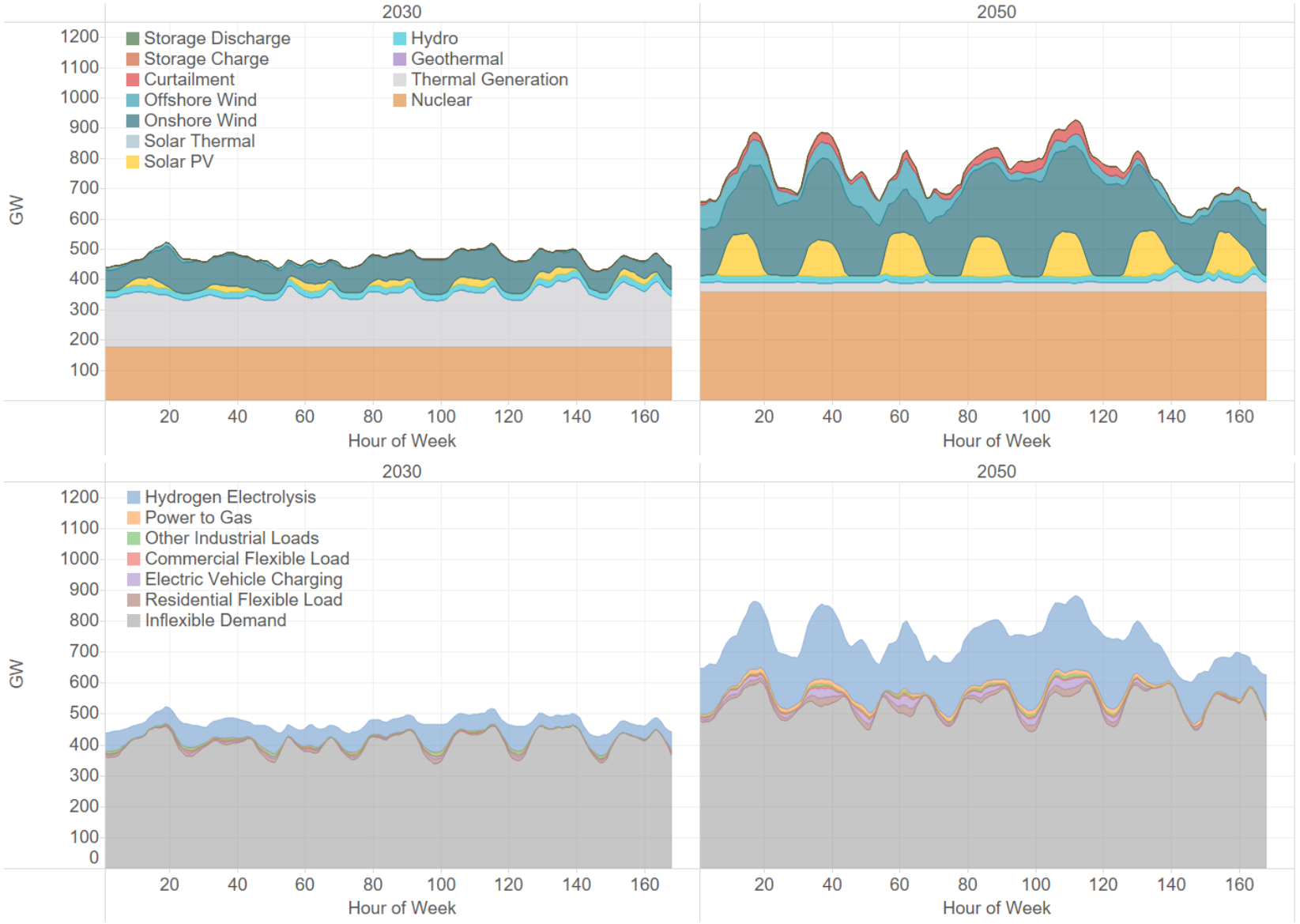




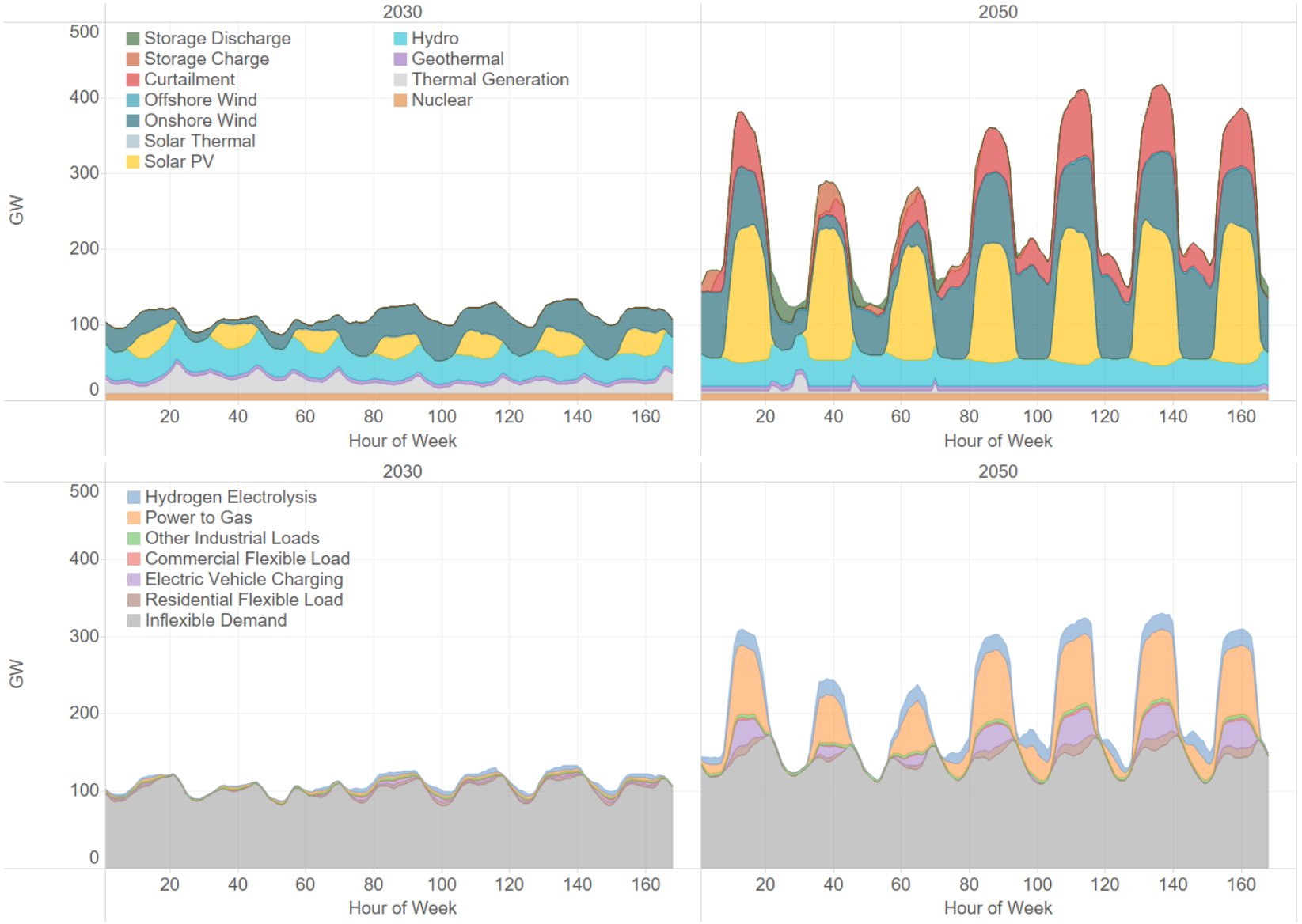
Eastern Interconnection, High Renewables



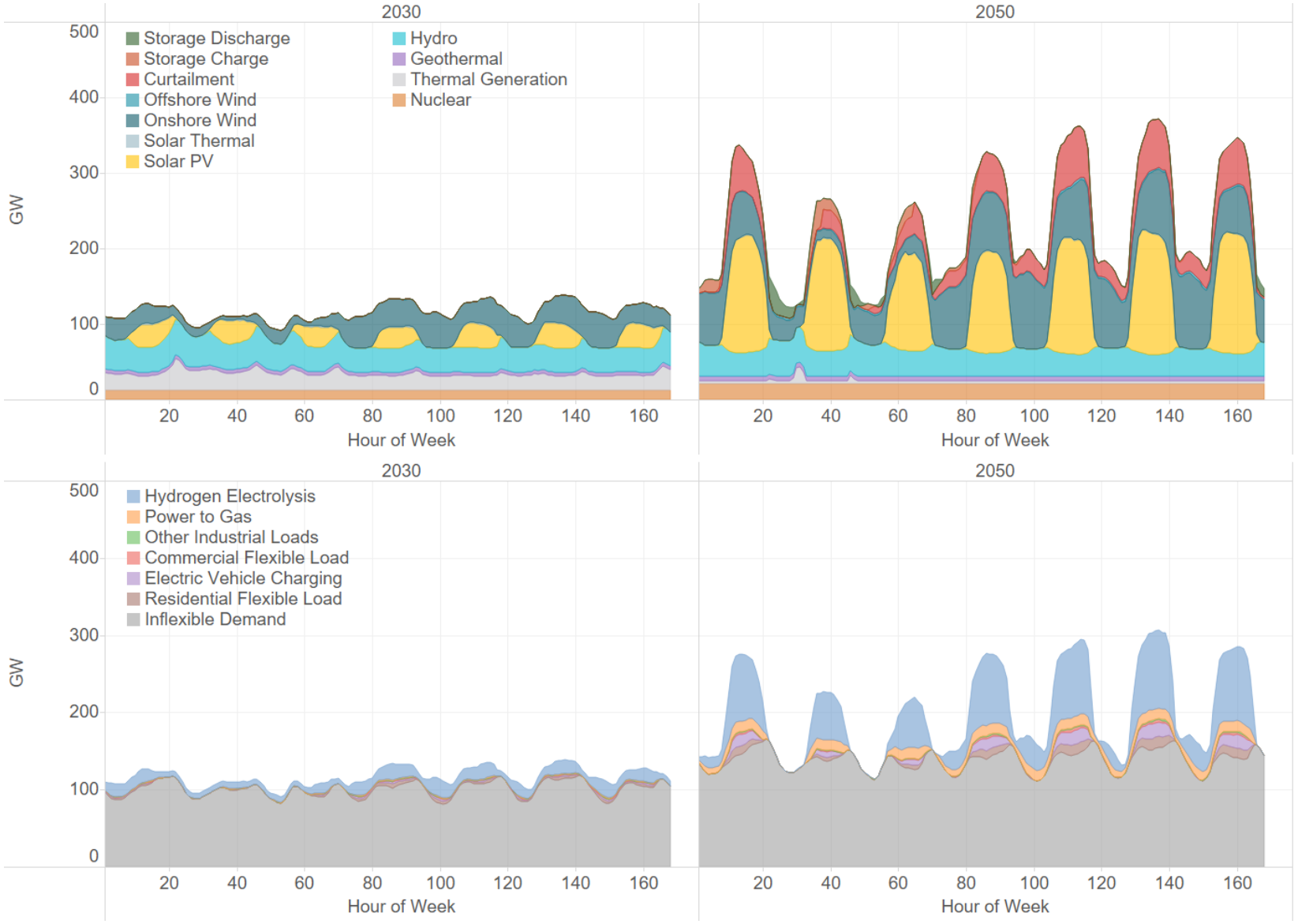
Eastern Interconnection, Nuclear



Western Interconnection, High Renewables



Western Interconnection, Nuclear



Observations on Nuclear-Renewable Synergies

RE-Nuclear Shared Challenges/Opportunities Under Deep Decarbonization

- Rapid & large-scale expansion of generation
- Coordination with large-scale electrification
- Regionalization of grid planning & operations
- Siting of generation, trans, flexible demand
- Large-scale P2G (H2, SNG) & liquid fuels
- Sustainable utility business model
- Wholesale market structure
- Public perceptions of readiness, acceptability
- Policy community conventional wisdom

Energy System Perspective on Nuclear-Renewable Synergies

- Deep decarbonization is a system problem
  - Requires coordination across sectors, between supply and demand sides
- Evaluate solutions from system cost perspective
  - Individual measure cost (e.g. LCOE, $/ton) poorly represents net cost of supplying and using energy
- Inflexible generation has system solutions
  - Very large scale flexible demand good for both high nuclear & high renewables systems
- Rethink supply side drop-in solutions
  - E.g. battery storage, in-situ shaping, dispatchable nuclear may look less attractive from system view

Market Design Challenges in High Nuclear & High Renewable Electricity Systems

- Variable costs are near zero
  - How to allocate fixed costs on time dependent basis in economically rational way?
- Meeting net load, not traditional load, is new operating reality
  - How to reflect equivalent value of supply and demand side flexibility → symmetrical wholesale market design?
- Supply and demand side procurement closely linked
  - How to send signal to potential demand side developers? → avoid premature building of integration solutions e.g. storage
- New asset utilization paradigm
  - Net load factor, not traditional load factor

THANK YOU

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www.deepdecarbonization.org

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